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A MATRIX ELEMENT OF A SOLID STATE ULTRASONIC IMAGE CONVERTER USING A LIGHT EMITTING DIODE IN A NON-SCANNING DISPLAY

PETER ARNOLD TRUMP

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THESIS

A MATRIX ELEMENT OF A SOLID STATE ULTRASONIC IMAGE CONVERTER USING A LIGHT EMITTING DIODE IN A NON-SCANNING DISPLAY

by

Peter Arnold Trump

Thesis Advisor: G. L. Sackman

September 1971

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A Matrix Element of a Solid State Ultrasonic Image Converter Using a Light Emitting Diode in a Non-Scanning Display

by

Peter Arnold Trump
Lieutenant, United States Navy
BSEP, University of Kansas, 1965

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

from the

NAVAL POSTGRADUATE SCHOOL
September 1971

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ABSTRACT

A mosaic transducer array at the focal plane of an acoustic lens followed by suitable electronic circuitry can be used to produce an image of an object.

Previous work in developing such a system has resulted in switching and scanning circuits required to use a cathode ray tube display. This report is a study of a design which would use a mosaic of light emitting diodes to produce the image directly without recourse to scanning. A single channel of such a system has been designed which responds to voltage levels at the transducer of less than ten microvolts at a frequency of 500 KHz. The channel responds to signal levels over a dynamic range of greater than 40 dB and produces light with a dynamic range of 28.9 dB, with 230 to 500 milliwatts power required depending on the input signal level. A discussion of performance, size and cost is included.

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I. INTRODUCTION

Low natural light levels and high absorption of light energy in water have resulted in many efforts to utilize alternate energy forms to detect and identify underwater objects. Acoustic energy in the ultrasonic frequency range is a good choice since the wave length is short enough to provide good resolution of most targets of interest. The ambient noise level of the ocean environment is low in the 500 KHz range where it is of the same magnitude as the thermal noise. Reasonable projector power levels can provide useable detection ranges despite absorption and scattering losses.

Just as in optical systems, acoustic energy reflected from an object can be focused by a lens. The pressure intensity of the acoustic wave pattern produced at the focal plane of the lens contains the same information as does the light intensity pattern produced at the focal plane of an optical lens. The pressure pattern can be sampled with electromechanical transducers in sufficient detail so that an analogous visible image can be reconstructed through electronics. Various schemes for accomplishing this image conversion have been reported in theses by LT K. G. Robinson (1), LT A. F. Barta (2), LT R. J. Larkin (3) and LT J. D. Pearson (4), all of the Naval Postgraduate School.

Robinson and Barta used a 9x9 transducer array connected by cable to 81 tuned 450 KHz amplifiers, detectors and sampling switches. Scanning circuitry converted the 81 pressure intensity samples of the acoustic pattern into a square array of 81 intensity modulated spots on the face of a cathode ray tube. This system was limited by the crosstalk and attenuation losses of the cabling.

Larkin designed and built a 16 channel printed circuit board of a proposed 32x32 array. The board included a 16 element line array of transducers, and a like number of linear amplifiers, detectors and sampling switches. Shift registers provided serial multiplexed samples of the 16 channels. The design would permit an entire 32x32 array to be packaged in as little space as 9x9x6 inches. The sequence of 1028 samples was to be cabled to another unit for display.

Pearson developed the idea of using one of Larkin's printed circuit boards mounted on the radius of a rotating cylinder to combine mechanical scanning with electronic scanning and reduce cost.

All these designs share in common the cathode ray tube as the device for producing the visible analog of the acoustic pressure intensity pattern. Although the CRT is a time-tested and proven means for accomplishing such conversion in many systems, it does have some drawbacks. The CRT requires high voltage power supplies and deflection circuitry. In the systems described above, the deflection circuits

must be synchronized with the sampling circuits to provide a meaningful display. Nevertheless, there has been no practical alternative. An early television system built in Germany before World War II used an immense array of incandescent lamps to produce an image. However, the extremely low efficiency of the incandescent lamp, in addition to its poor linearity, makes this approach infeasible. It is highly desirable, however, to produce an image directly without recourse to scanning and sampling techniques and a CRT display. All that has been lacking is a small, linear, and efficient light source. With the advent of the low cost luminescent or light emitting diodes (LED), a small, simple, and compact image converter is a practical possibility.

A single channel of an ultrasonic image converter could consist of a transducer element, an amplifier and detector, and an LED with a suitable driver circuit. This is shown in block diagram form in Figure 1. The two principle advantages to such a system are immediately obvious. Elimination of switching networks, sampling logic, synchronization problems and the entire CRT considerably reduces the cost and complexity. Elimination of cabling improves performance. Larkin sought a single channel cost of $10 exclusive of the printed circuit board and achieved a cost of $13. This, of course, is also exclusive of the display unit cost. The goal of this thesis project is to design and test a single channel of an LED image

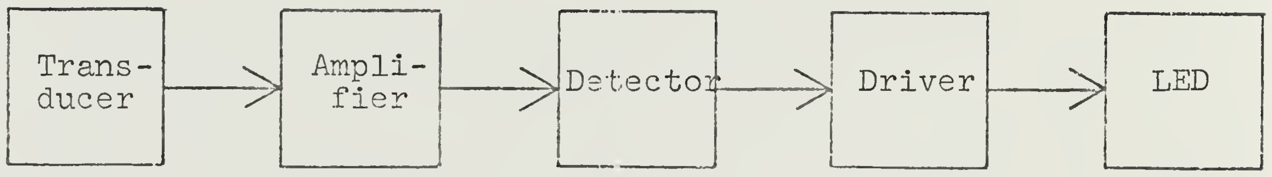


FIGURE 1. SYSTEM BLOCK DIAGRAM

conversion system which will cost no more than $10. Since such a system would include the display, the advantage of reduced complexity is compounded by the reduced cost.

II. CIRCUIT DESCRIPTION

The elements of a single channel design are discussed in reverse order because that was the sequence of design. The LED, driver circuit, detector, amplifier and transducer were fitted together back to front to meet the following criteria.

A. OBJECTIVES

1. The LED should produce visible light of sufficient intensity that a recognizable image can be formed.

2. The minimum signal level to which the circuit will respond should be no greater than ten microvolts.

3. The amplifier should be broadband untuned and capable of providing 40 dB dynamic range, i.e., ten microvolts to one millivolt at the input.

4. The saturation characteristics of the amplifier should be such that strong signals will not harm the LED.

5. The transducer should discriminate against unwanted signals at other than the 500 KHz frequency.

6. The total cost on a single channel basis exclusive of power supplies and circuit boards should not exceed $10.

B. LIGHT EMITTING DIODE

At this time, LED's typically produce light in a fairly narrow optical bandwidth in either the red or green wavelengths. Red light LED's can achieve 7.2% efficiency while

the green light LED's are somewhat less efficient. Mass production has resulted in low unit cost for many LED's. It can be small enough so that an array can provide the patterns of light necessary for an alpha-numeric display on a single substrate. Large LED's can provide darkroom lighting. An array of LED's would be a logical choice for the visible display end of an ultrasonic image converter.

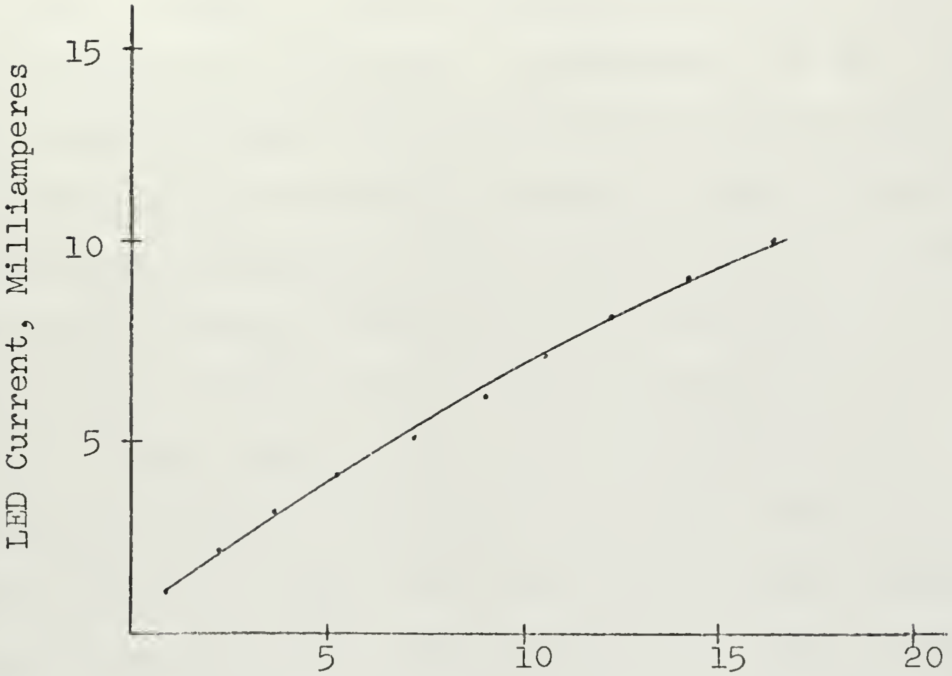
The electrical characteristics of the LED are similar to those of most solid state diodes, except that the forward offset voltage is higher, corresponding to the electron-volt energy of the longest wavelength light produced by the diode. Once conduction begins, light intensity is a linear function of forward current. The forward dynamic resistance of the LED is about two ohms.

Many manufacturers produce LED's in a bewildering variety of sizes and shapes, colors, and characteristics. The Monsanto MV 10A was selected for low cost, small size, and high efficiency. Other LED's would perform as well such as the similar Texas Instruments TI6205. The MV 10A is a diffused gallium arsenide phosphide diode which produces red light with a spectral line half-width typically 400 Angstroms centered at 6700 Angstroms. The forward voltage versus forward current characteristic is linear from three milliamperes to the maximum 70 milliamperes with a forward voltage offset of 1.6 volts. The diode is packaged with a single lead in a case which is nominally 0.1 inch in diameter. Additional details are provided in Appendix A.

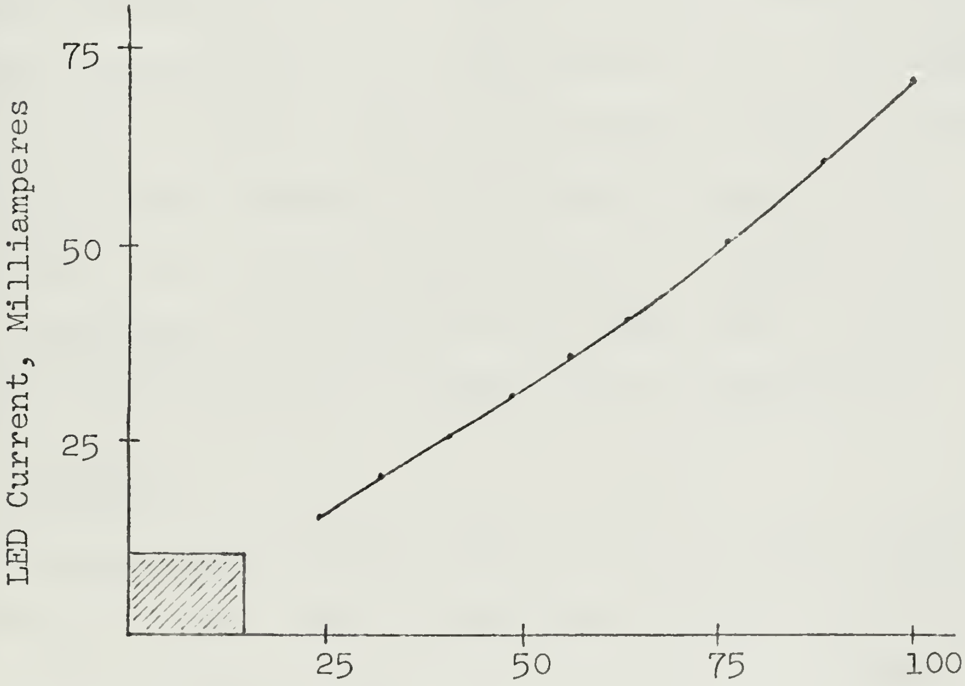
C. LED DRIVER

Designing a circuit which translates a linear signal of 40 dB dynamic range into a linearly varying current through a two ohm dynamic resistance is an interesting problem. However, good results can be achieved with an economy of components. To take advantage of the entire linear range of the MV 10A, the current must vary between about three milliamperes and 70 milliamperes (Figure 2). Since the light output of the LED is linearly related to the current, this is somewhat less than the desired 40 dB dynamic range. In addition, to avoid the possibility of destroying the LED with excessive current, it is desireable that the circuit saturate before the maximum LED current of 70 milliamperes is achieved. The LED is especially vulnerable to thermal damage from over current since one face of the diode is necessarily completely free of a heat sink because the light must escape. High current operation requires adequate heat sinking, especially if the duty cycle is high or continuous operation is contemplated. What remains of the dynamic range can be extended into the non-linear portion of the LED characteristic in the region of less than one milliampere. However, the light is of such low intensity as to be barely visible. A larger LED might provide greater dynamic range, but the small size of the MV 10A is considered more important.

Since the maximum LED current is fixed when the maximum light intensity is selected, the power which must be



Percentage Light Intensity, Normalized to 100% at 70ma
Crosshatched Area of Graph Below



Percentage Light Intensity, Normalized to 100% at 70ma

FIGURE 2. LIGHT OUTPUT OF THE MV10A

dissipated by the LED and its driver is a linear function of the supply voltage. Therefore, it is desirable to fix the supply voltage as low as possible and still achieve a linear response to the input. Furthermore, it was found that the driver must dissipate approximately the same amount of power as the LED to assure a linear response. The maximum rated dissipation of the MV 10A is 150 milliwatts. The need for thermal stability led to the selection of a small plastic encapsulated silicon transistor for the driver. A heat sink on the driver transistor and DC feedback contribute to thermal stability. The driver circuit, Figure 3, uses fixed bias with a small emitter feedback resistor. Two power supplies are used for the driver. This has the effect of fixing the base below ground potential with the result that the detector is always forward biased and contributes to the zero signal bias current. Thus, there is no offset voltage so that the LED driver responds to the smallest input to the detector. In a display consisting of a large array of LEDs, the requirement for both plus and minus power supplies does not add significantly to either cost or complexity.

D. DETECTOR

The detector circuit, Figure 4, is a simple diode envelope detector with an additional diode to provide the bias current path for the LED driver, mentioned above, and to act as a negative clipper. The rise time of the detector is determined by the output resistance of the amplifier

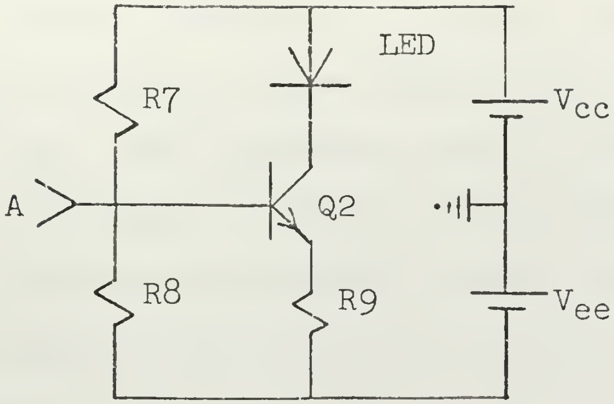


FIGURE 3. LED DRIVER

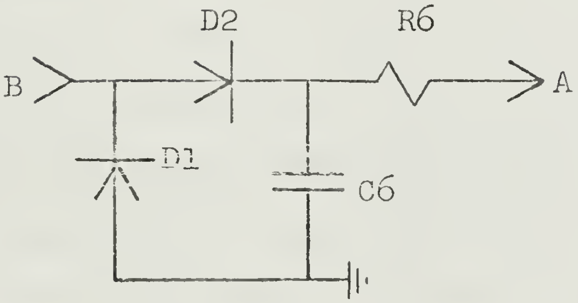


FIGURE 4. DETECTOR

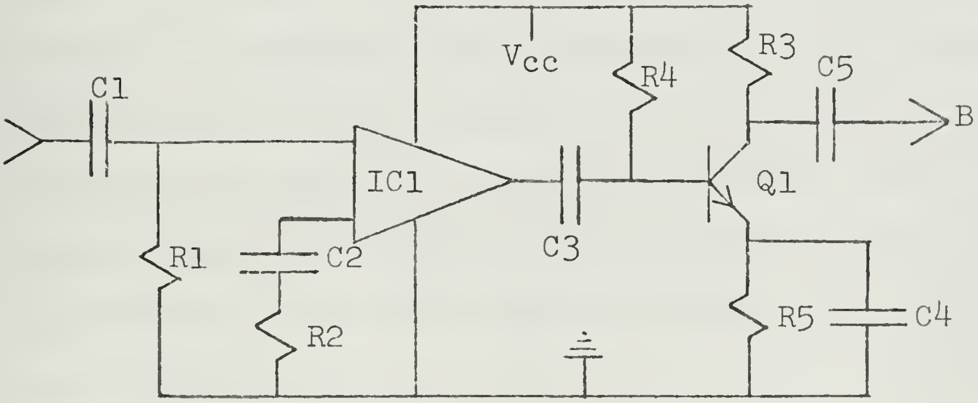


FIGURE 5. AMPLIFIER

driving the detector, the forward resistance of the diode, and the detector capacitor. Likewise, the fall time is determined by the detector capacitor and the coupling resistor, R6. The operating limits of the LED are set with the fixed bias, resistor, R7, adjusted for the desired minimum LED current, and the coupling resistor, R6, adjusted for the desired maximum LED current with the maximum detector output.

E. AMPLIFIER

The maximum detector output, in turn, is determined by the saturation characteristics of the amplifier, Figure 5. The minimum detectable signal level was set at ten microvolts in the design goals. This signal level must cause a measureable increase in the LED current. To achieve 40 dB dynamic range in the signal end of the image converter, an input of one millivolt must cause the amplifier to approach saturation. The detector requires an input voltage swing beyond the linear limits of the integrated circuit amplifiers available, so the detector driver was designed with discrete components. The characteristics of the amplifier were chosen to avoid damage to the LED under any reasonable continuous signal. The amplifier sections share a common single ended power supply which can be adjusted to achieve the desired saturation characteristics. The collector, bias and emitter resistors, R3, R4 and R5, were chosen to give maximum gain with the detector circuit load. The transistor

is the same as that used in the LED driver and was also provided with a heat sink, in addition to the AC and DC feedback, for stability.

An integrated circuit provides the other portion of the amplifier. The particular IC used contains four identical high gain wide band amplifiers; it is thus suitable for four adjacent channels. Details of the RCA CA3048 integrated circuit are found in Appendix B. Negative feedback for stability is provided by raising the inverting input above AC ground through C2 and R2. The gain of the amplifier is determined by R2. Some care must be taken in positioning the components of the amplifier to avoid instability through unwanted feedback paths. In the absence of the transducer source impedance, R1 is necessary to prevent the amplifier from oscillating.

F. TRANSDUCER

Barium titanate transducers are electrostrictive ceramics with a permanent electric polarization which produce electric signals under stress. A whole matrix of transducers is formed by making a series of parallel cuts nearly through the thickness of a plate of polarized barium titanate along two sets of mutually perpendicular lines, Figure 6. The resonant frequency of each little transducer thus formed is dependent on its thickness according to the relation of equation

$$\text{Resonant frequency} = \frac{\text{Velocity of sound in the crystal}}{\text{2 times the length of the crystal}}$$

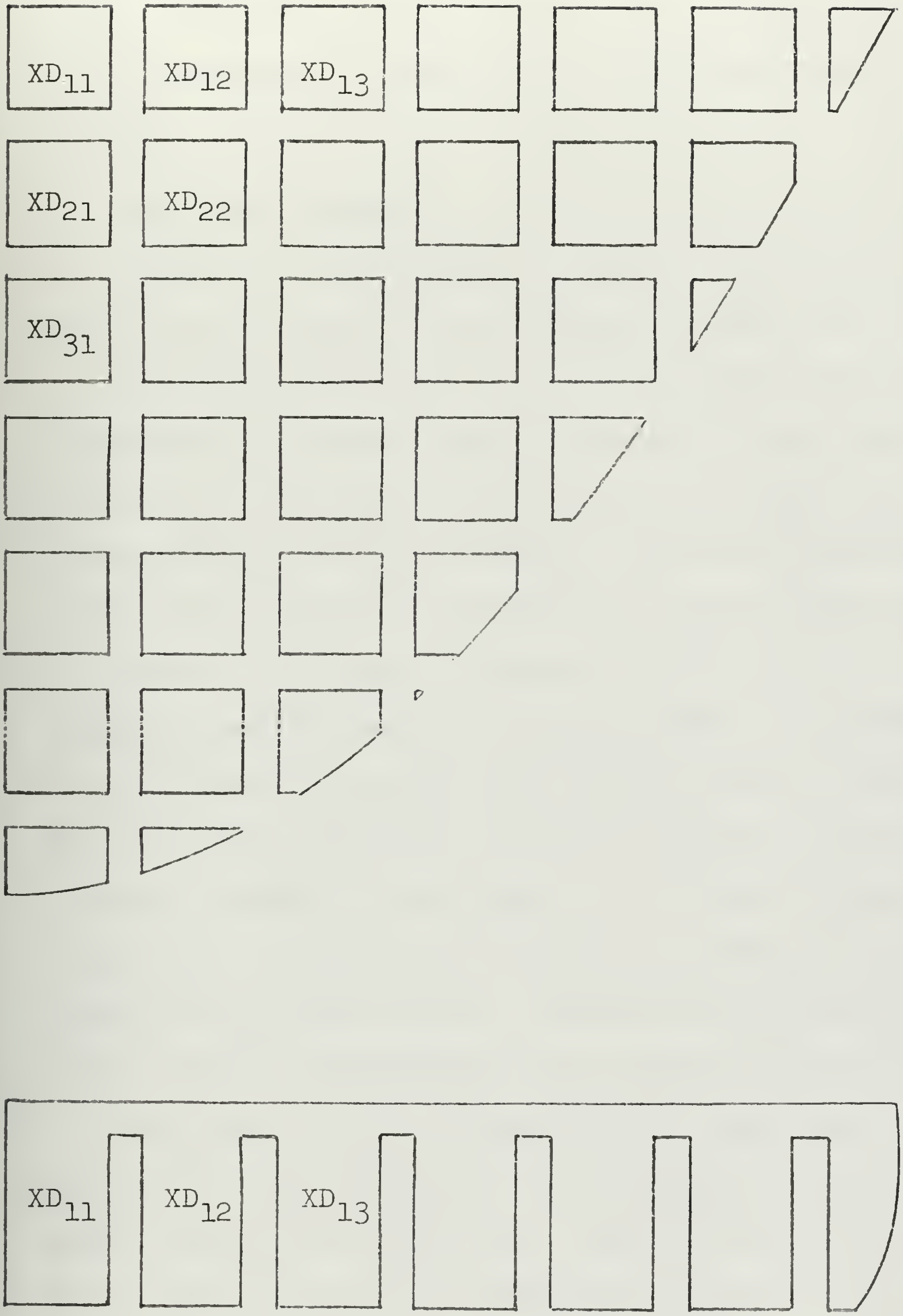


FIGURE 6. PLAN AND END VIEWS OF THE TRANSDUCER ARRAY,
SCALE APPROXIMATELY 10:1

When such a transducer is loaded with a column of water, its source impedence is approximately one kilohm, and it produces approximately ten microvolts per microbar of sound pressure.

G. COMPLETE CIRCUIT

Figure 7 is a schematic drawing of the complete circuit for a single channel of an ultrasonic image converter.

The 2N3417 transistor is rated for 360 milliwatts dissipation. The heat sink consisted of a one inch square of 0.040 inch thick aluminum pressed onto the case. The ten ohm value for R9 represents a compromise between the desire for DC feedback to increase stability and the desire to minimize the supply voltages to minimize overall dissipation. The ten ohm value also provides a convenient voltage drop with which to monitor LED current during bench tests. The fixed bias resistor, R7, was selected to provide an LED current of about 2.5 milliamperes with the detector circuit connected. The clipper and detector diodes, D1 and D2, are germanium switching diodes. Substitution of silicon diodes would require a shuffling of the values in the fixed bias.

The values of R3, R4 and R5 in the amplifier were determined experimentally to provide maximum gain with the normal detector and LED load. The AC feedback is restricted to the bias resistor R4 with bypass capacitor C4. Similarly, the value of R2 was determined experimentally to achieve the gain required. Resistor R1 is required only when the transducer is not in the circuit and the source has a high impedance.

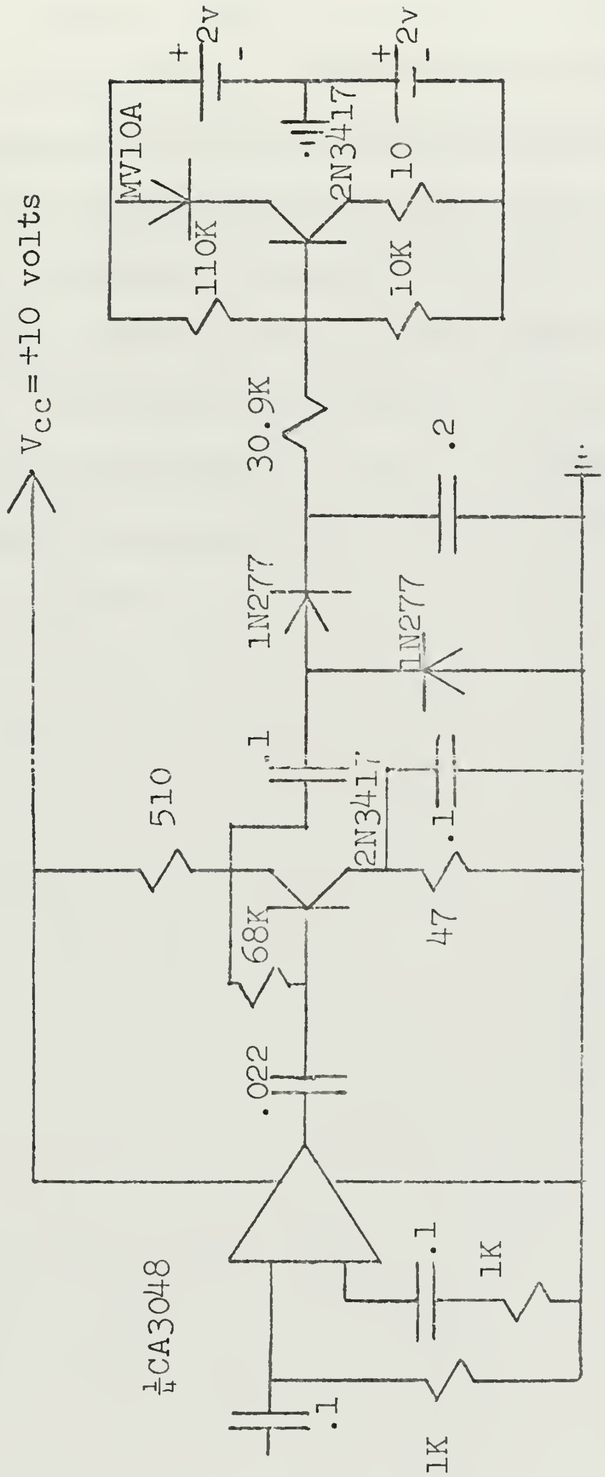


FIGURE 7. COMPLETE CIRCUIT

The power supplies also were selected in a pragmatic fashion. The two volt supplies for the LED and driver circuit were the minimum that gave a linear input-output characteristic to the driver. The maximum dissipation in continuous operation is 280 milliwatts exclusive of the bias currents. The amplifier power supply was chosen to give the desired saturation characteristics. The two sections of the amplifier each dissipate approximately 110 milliwatts. Therefore, the maximum dissipation per channel would be 500 milliwatts, and the average somewhat less. The minimum dissipation per channel with no signal input is 232 milliwatts.

III. EXPERIMENTAL RESULTS

As each section was added to the circuit, working back from the LED, the LED current was determined as a function of the input voltage. The driver circuit provides no limiting, given a sufficient input it will exceed the maximum rated current and destroy the LED. This is true also of the detector circuits. The detector and driver combination provides a linear LED current response for detector input voltage between ten millivolts and three volts rms. The input resistance of the detector was measured as 8 Kohm. Because of the vulnerability of the LED to excessive currents, limiting must occur to prevent damage to the LED from high signals.

Limiting is achieved in the amplifier section preceding the detector. Figure 8 illustrates the dummy load current plotted for a range of amplifier input voltages. The dummy load of 3.9 ohms was used to prevent accidental damage to the LED while exploring extreme values of input. Figure 9 is a plot of the same variables with the LED in the circuit and the amplifier supply adjusted to ten volts.

Figure 1 shows the relationship between LED current and light intensity for the range of current in Figure 9. The second half of the amplifier begins to change the LED current with an input of -61.4 dB re 0.775 volts which corresponds to 660 microvolts. Thus the integrated circuit

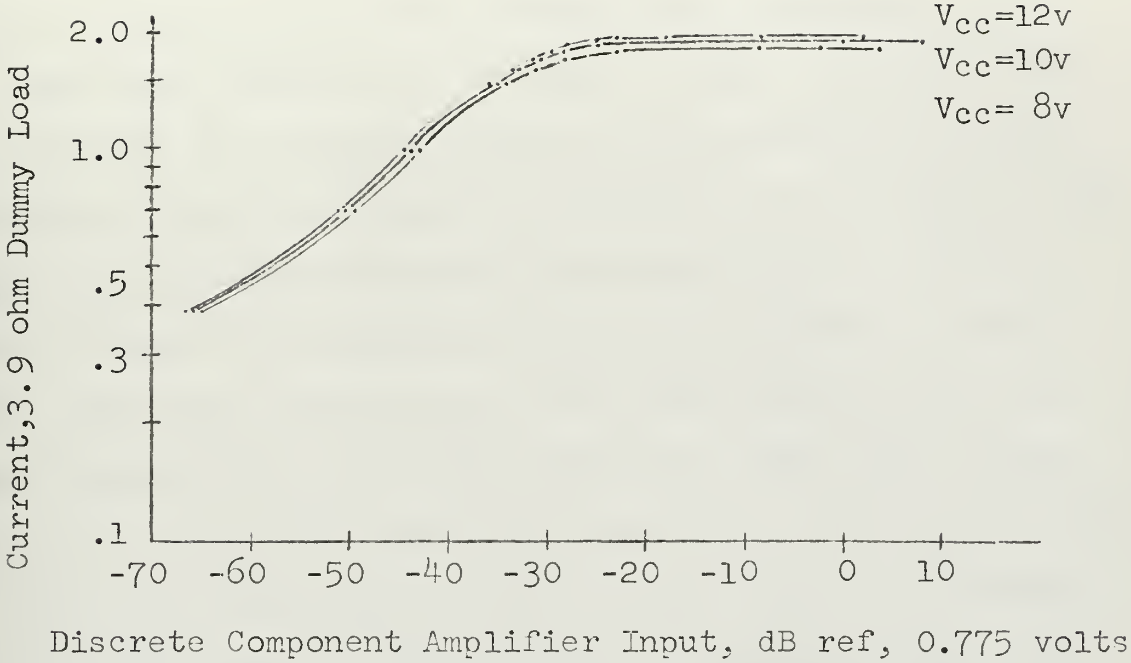


FIGURE 8. Saturation Characteristics of the Discrete Component Amplifier with a Dummy Load

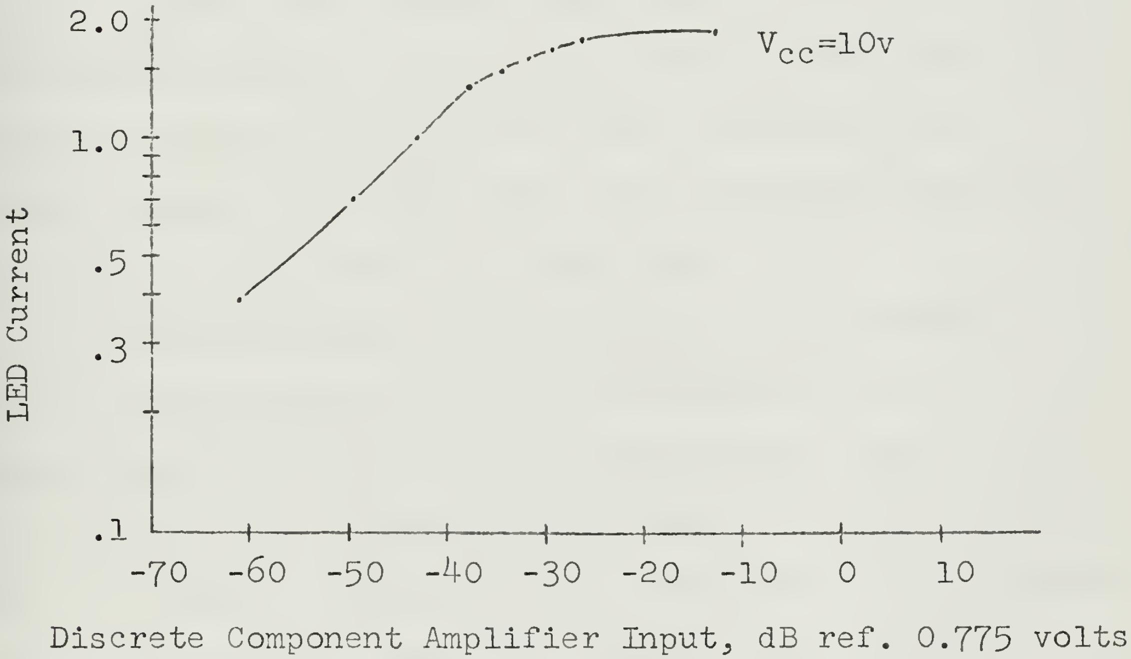
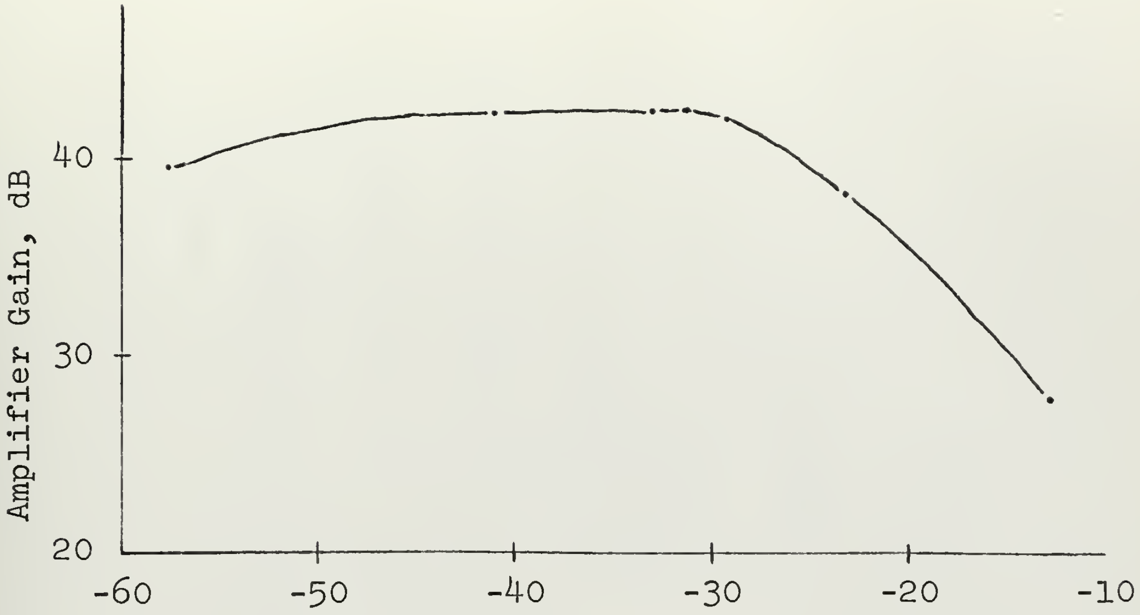


FIGURE 9. Saturation Characteristic of the Discrete Component Amplifier.

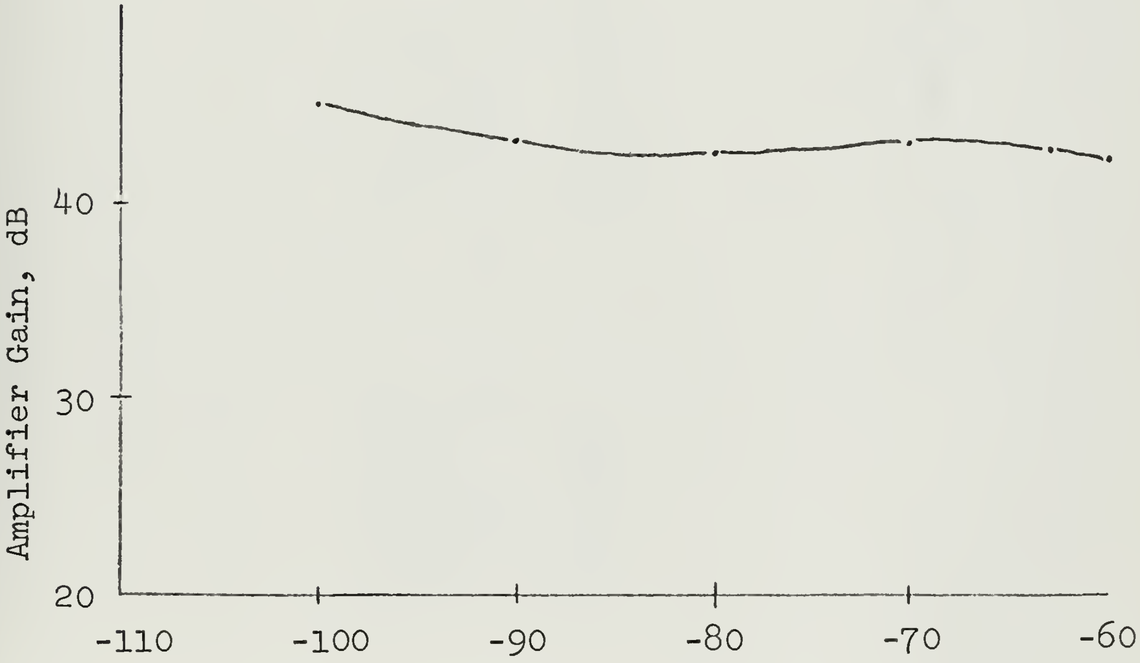
must provide an effective stage gain of 40 dB including coupling losses to meet the design objective for sensitivity. Figures 10 and 11 show the measured in circuit gain of the two amplifier sections for a range of input voltage. The measurements are tricky to make on the integrated circuit amplifier since the frequency of interest lies nearly in the commercial broadcast band and the sensitivity is that of a good FM tuner. In addition, there was no meter available with comparable sensitivity so the input levels were determined indirectly. The method employed, while not of great precision, gave good reproducible results. The arrangement is shown in block diagram form in Figure 12. It consists of a Wavetek Model 112 VCG driving a Hewlett-Packard 467A variable gain amplifier. The output of the amplifier was reduced (60 dB) by a Jerrold Electronics AV-50 calibrated RF attenuator before entering the circuit under test. The output of the H-P 467A amplifier was monitored with a Hewlett-Packard 400D VTVM which was also used to measure the output of the amplifier under test.

In pulsed operation, the rise time of the detector output was determined with an oscilloscope to be 1.2 milliseconds with the detector capacitor, C6, equal to 0.2 microfarads and the coupling resistance, R6, equal to 31 Kohm. An image converter would likely use 0.1 millisecond pulses with a pulse repetition rate of ten pulses per second. These requirements are antagonistic. To avoid flicker, the decay time constant of the detector should



Discrete Component Amplifier Input, dB ref. 0.775 volts

FIGURE 10. Gain Characteristic of the Discrete Component Amplifier.



Integrated Circuit Amplifier Input, dB ref. 0.775 volts

FIGURE 11. Gain Characteristic of the Integrated Circuit Amplifier

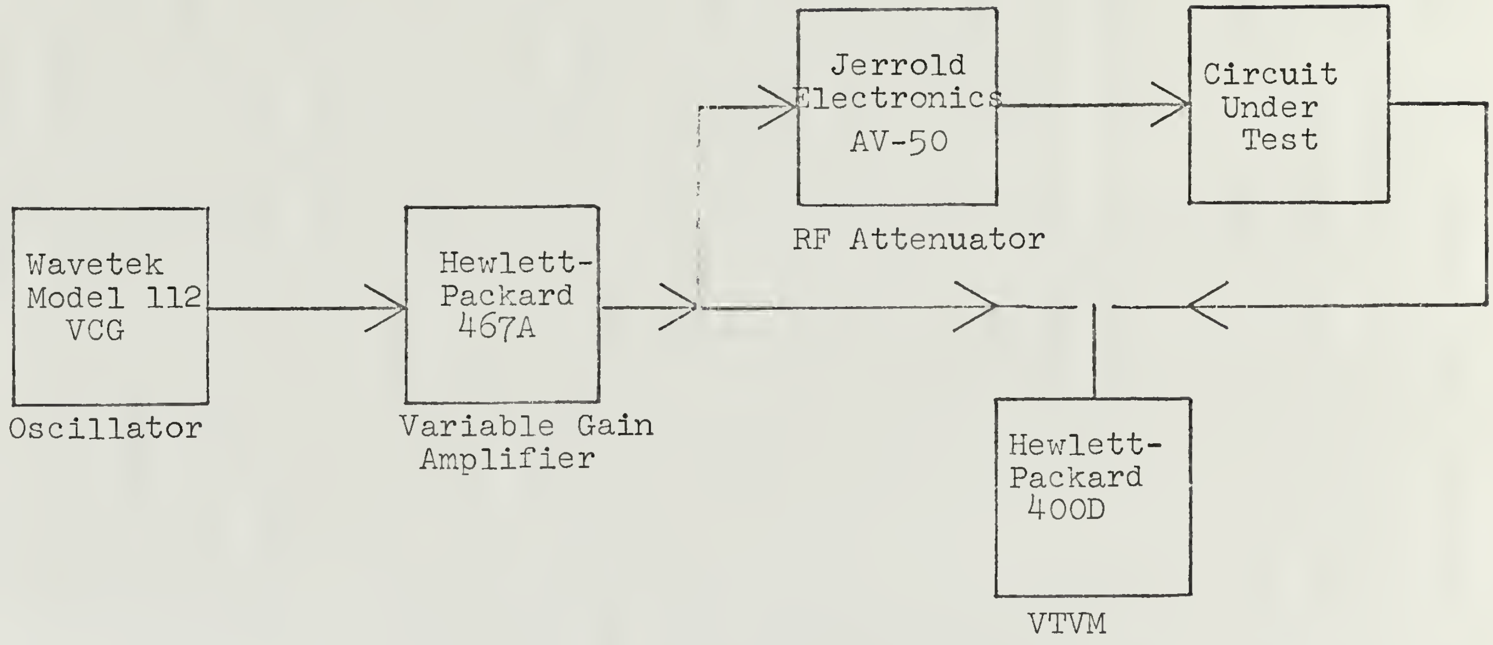


FIGURE 12. EXPERIMENTAL SETUP, BLOCK DIAGRAM

approximate the period between pulses, 100 milliseconds. However, the rise time must be much shorter than the pulse width or about 0.01 milliseconds. Assuming the coupling resistor was unchanged in value, C6 would become approximately 3 microfarads. The rise time with C6 only 1.2 microfarads was measured on the oscilloscope as 8 milliseconds, much too slow.

An attempt was made to improve the rise time of the detector by using an NPN transistor in place of the detector diode, D2. The idea was that the charging current would be multiplied by the beta of the transistor. Instead, the rise time increased from 1.2 milliseconds to 15 milliseconds and the whole amplifier-detector-driver relationship was adversely affected. Some of this can be attributed to the difference in the junction characteristics between a silicon transistor (2N3704) and the germanium diode (1N277). The idea was not pursued any further for lack of time. Possibly, some improvement might result from an emitter follower buffer between the amplifier and the detector, but this idea likewise was not pursued. As the circuit now stands it is well suited to CW operation but not pulsed carrier operation. Both sections of the amplifier respond fast enough, but the output impedance of the discrete component amplifier is too great to achieve a fast pulse rise time in the detector.

The input voltage versus output (LED) current experiment was repeated for the entire circuit for amplifier supply

voltage of 8, 10, and 12 volt. As when only the discrete component section of the amplifier was considered, Figure 8, the results led to the choice of ten volts for the amplifier power supply. The curves are shown in Figure 13.

Finally, the amplifier was connected to a member of a transducer matrix such as described above. The matrix was held in place by plexiglass fingers against the surface of a metalized mylar window in the side of a small water tank. A Gulton Industries 2D15 transducer provided the ultrasonic excitation in the water which was detected by the transducer. The metal film on the one mil thick mylar served to reduce any electromagnetic coupling between the transducers. It proved possible to drive the circuit over the entire range of LED currents as with a direct signal input.

No attempt was made to determine the sound pressure level at the receiving transducer as a function of frequency. The resonant frequency of the 2D15 is 616 KHz. The small size and pressure release boundaries of the tank gave rise to an exceedingly complex standing wave pattern which was strongly affected by frequency. Nothing definitive can be said, therefore, about the effectiveness of the transducer as a first order bandpass filter. For a constant drive voltage to the transmitter, there was a local response peak in the vicinity of 500 KHz, though there was a much greater response peak at the 616 KHz resonance of the transmitter. Numerous other features of the frequency response

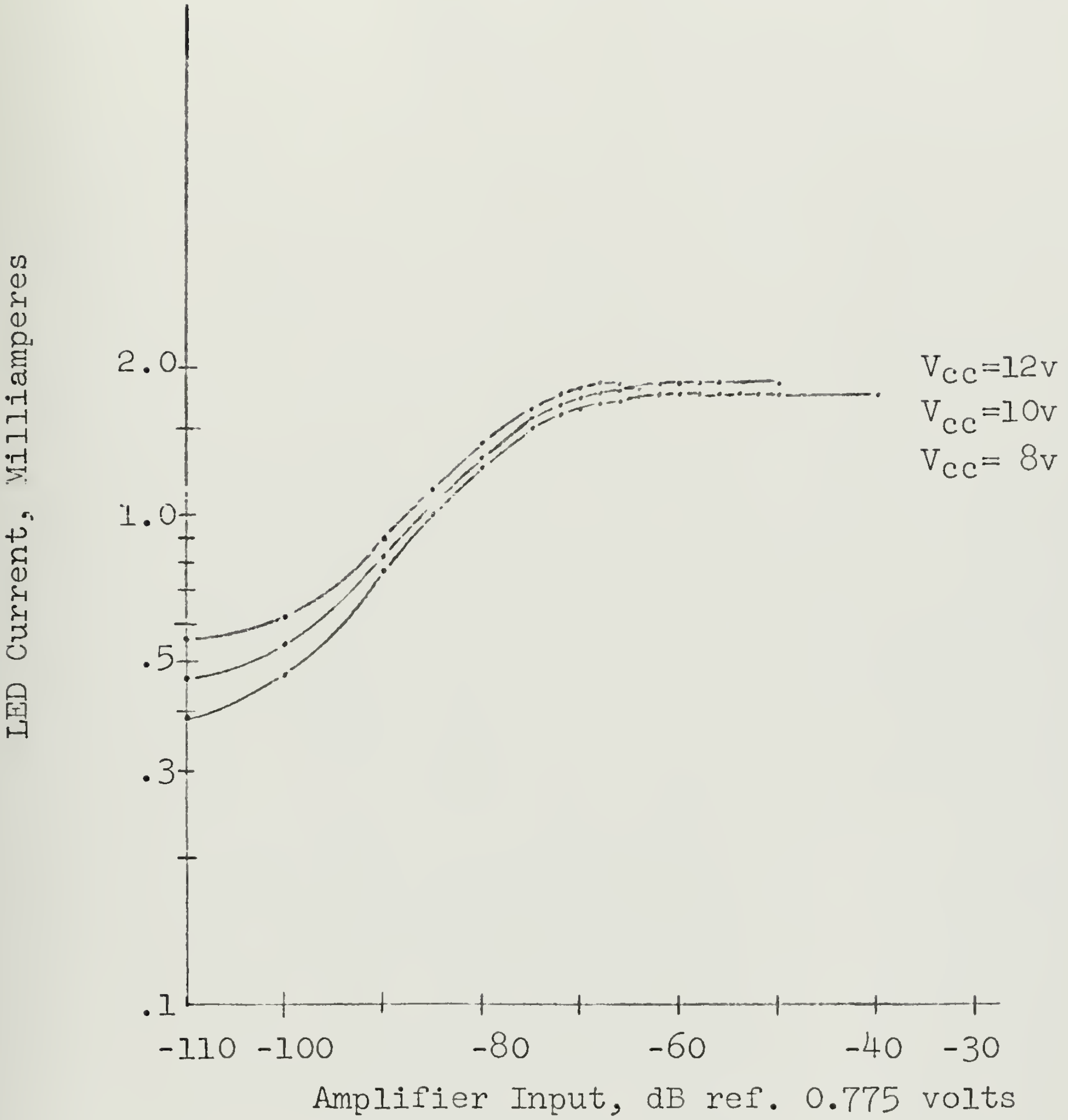


FIGURE 13. SYSTEM PERFORMANCE

characteristic were attributed to the standing wave pattern. It was noted that the circuit was quiet and stable in the absence of excitation to the transmitting transducer and the response as excitation increased also was smooth and quite free of any suggestion of electromagnetic coupling in addition to the ultrasonic coupling.

IV. CONCLUSIONS

The MV 10A light emitting diode produces light from an apparent spot size between 25 and 48 thousandths of an inch in diameter. A single diode viewed in an incandescent light (bench top) background produces light that is a small dull red spot at low current to an angry bright red at higher current. The eye loses the sense of differential brightness before full current is reached, but the contrast would be more apparent in a matrix all of the same color. It is felt that the MV 10A or similar LED's could effectively produce half-tone images with good contrast.

The input sensitivity of the entire circuit with one Kohm across the amplifier input was -100 dB re 0.775 volts or 7.75 microvolts, Figure 13. At this level the LED current has increased from the minimum bias level and the difference in brightness is easily seen in the single diode.

Likewise, in Figure 13, the entire dynamic range of the circuit is seen to include 50 dB or more, although the linear region is restricted to about 25 dB. The data does not include extremely high inputs with the amplifier supply set to ten volts, but the curve has flattened out as did the curve for an eight volt supply voltage. Extrapolating from this behavior and the similar results of Figure 8 in which a dummy load was used, it is determined that extreme signal conditions will not damage the LED.

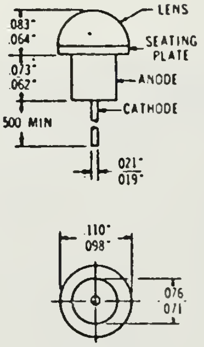
Nothing can be said about the effectiveness of the transducer as a filter. Measurements with known sound pressure levels in an anechoic environment should be made to make this determination.

Finally, the cost of the components is surprisingly low. Components for a single channel, including the whole price of the four-amplifier CA3048 cost only $14.11 or $11.08 if only $\frac{1}{4}$ the cost of the CA3048 is included. The cost per channel for the 1,000 or more channels necessary for a recognizable image is only $4.74. Details are shown in Appendix C.

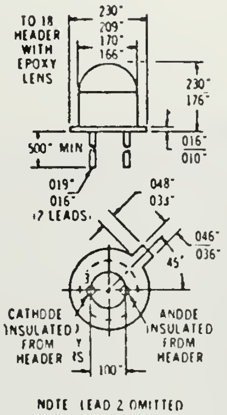
Thus, with the exception of the unresolved question of the transducer behavior, the design goals have been met with this design at a cost well below the objective. It is concluded that a direct image producing ultrasonic image converter which is small, simple, and relatively inexpensive is a practical possibility.

APPENDIX A

Package Physical Dimensions



MV10A
MV10A3



MV10B
MV10B3

Absolute Maximum Ratings

	MV10A MV10A3
Maximum Power Dissipation @25°c Ambient Temperature	150mW
Derate Linearly from 25°c	2.0mW/°c
Maximum Storage & Operating Temperature	-55°c to +100°c
Maximum Lead Solder Time @260°c (see note 4)	7.0 sec.
Maximum Currents and Voltages	
Continuous Forward Current	70mA
Peak Forward Current (1 μsec. pulse, 300 pps)	3.0A
Reverse Voltage	3.0V

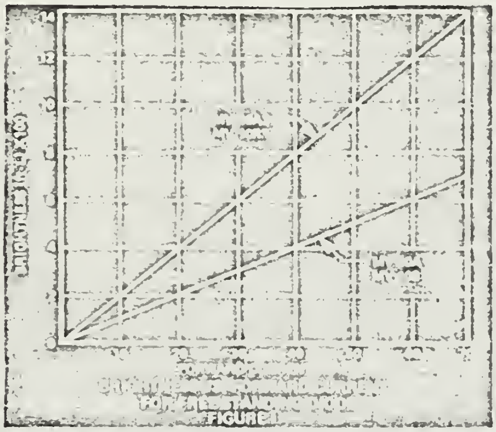
Electro-Optical Characteristics

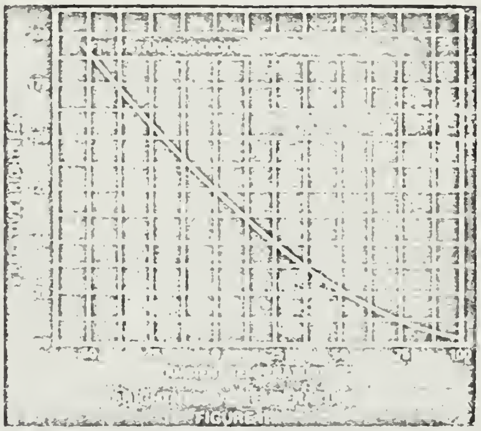
Characteristics	MV10A MV10B Min	Typ	Max	Unit	Test Conditions
Brightness (see note 1)		500		ft-L	I_f=50mA
Current to Produce 50ft-L (see note 1)			10	mA	
Total External Radiated Power (see note 2)		50		μW	I_f=50mA λ=6750Å
Peak Emission Wave Length	6300		7000	Å	
Spectral Line Half Width		400		Å	
Forward Voltage		1.65	2.0	V	I_f=50mA
Forward Dynamic Resistance		2.0		Ω	I_f=50mA
Capacitance		135		pf	V=0
Light Turn On and Turn Off		1.0		ns	
Reverse Current		0.3		μA	Vr=3.0v

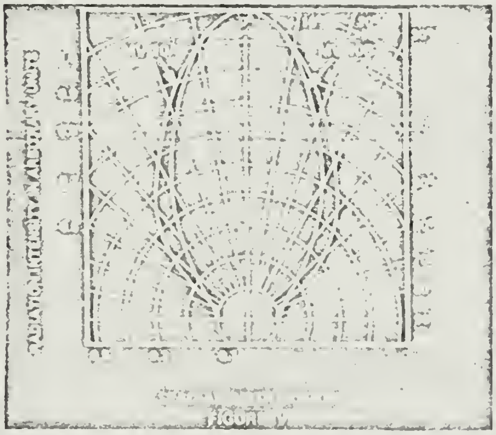
(25° c Free Air Temp

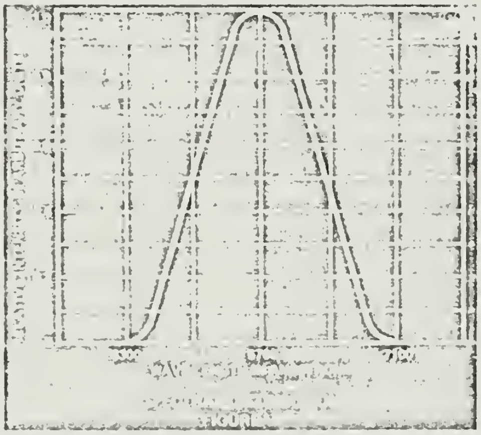
Thermal Characteristics (Typical)

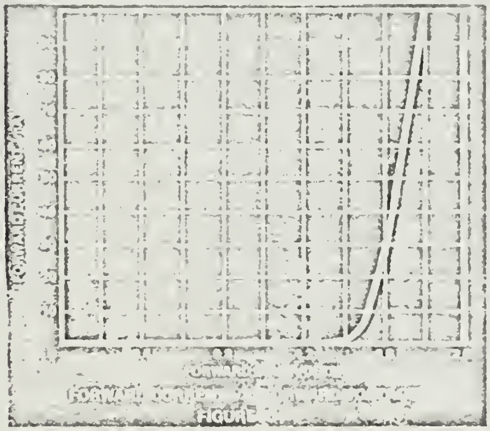
	MV10A MV10A3
Thermal Resistance Junction to Free Air (θ_{JA})	350° c/w
Thermal Resistance Junction to Case (θ_{JC})	170° c/w
Wavelength Temperature Coefficient (case temperature)	3.0 Å/°c
Forward Voltage Temperature Coefficient	-2.0 mV/°c

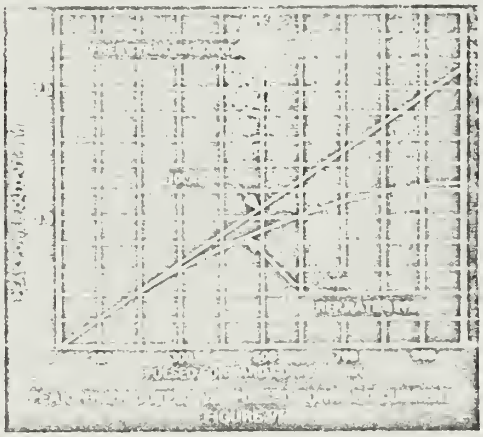












APPENDIX B

Amplifier Array CA3048

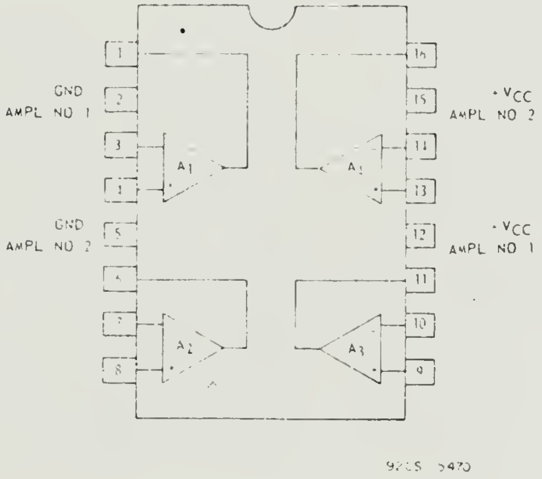
Monolithic Silicon

The RCA CA3048 is a silicon monolithic integrated circuit consisting of four independent identical AC amplifiers which can operate from a single-ended power supply.

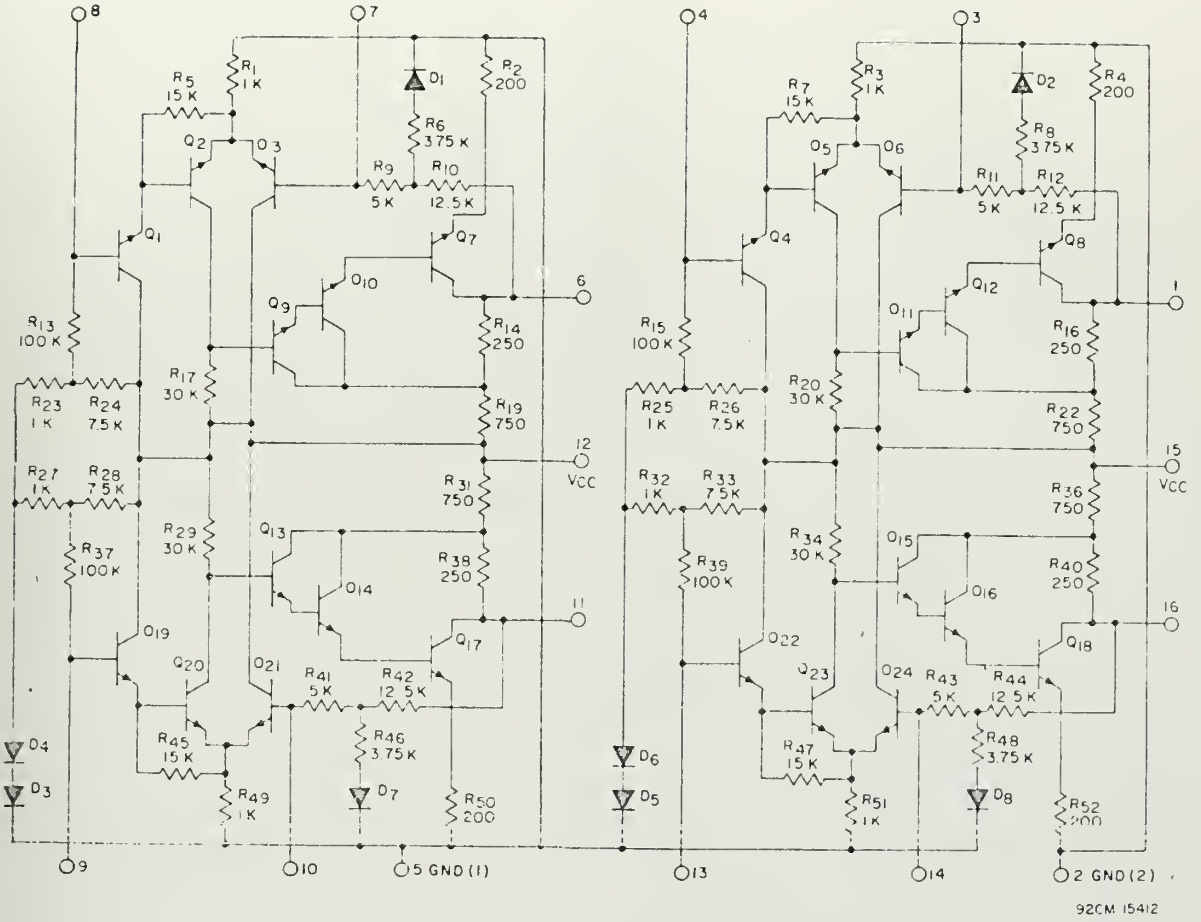
The amplifiers include internal DC bias and feedback to provide temperature-stabilized operation. They may be used in a wide variety of AC applications in which operational amplifiers have previously been used.

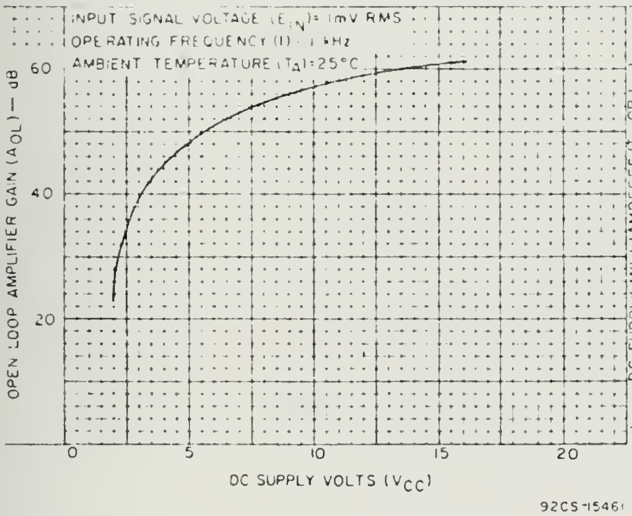
Each high gain amplifier has a high impedance non-inverting input, and a lower impedance inverting input for the application of feedback. Two power-supply terminals and two ground terminals are provided to reduce internal and external coupling between amplifiers.

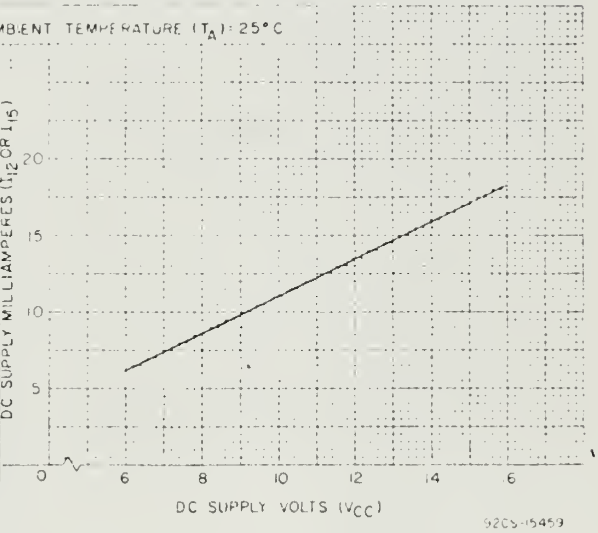
The CA3048 is supplied in a 16-lead dual-in-line plastic package.



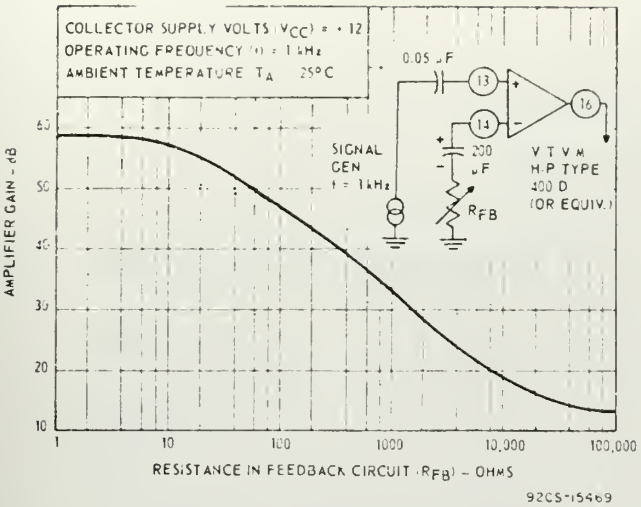
Block diagram for CA3048.



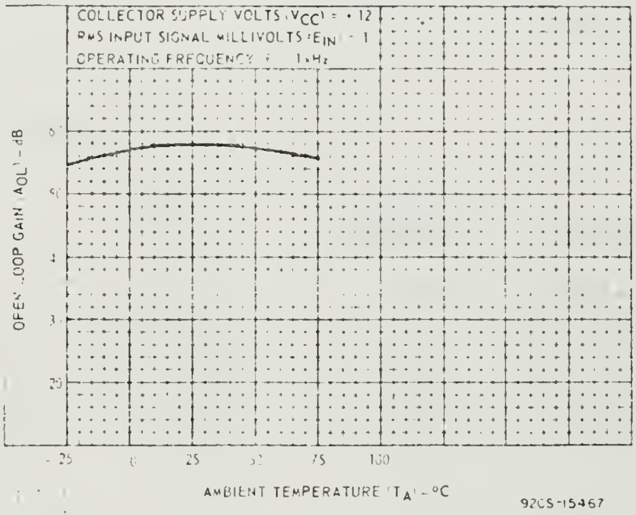




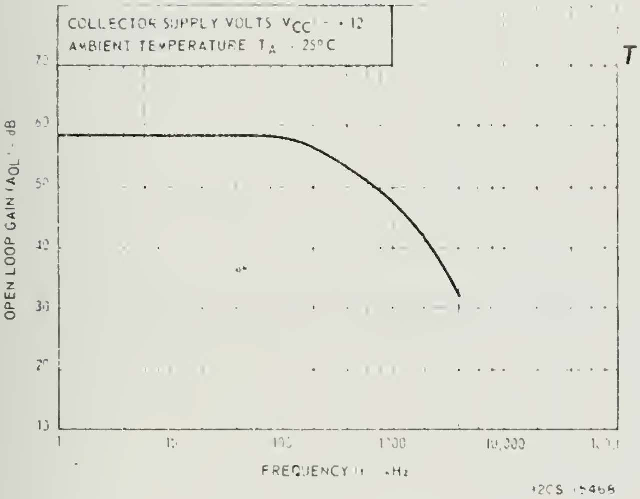
Typical amplifier gain vs DC supply voltage. - *Typical DC supply current vs supply voltage.*



Typical amplifier gain vs feedback resistance



Typical open-loop gain vs ambient temperature



· *Typical open-loop gain vs frequency.*

APPENDIX C

COST DATA

A. COST FOR A SINGLE CHANNEL

Component	Unit Price	Units/ Channel	Subtotal
RCA CA3048	$4.84	1*	$4.84
2N3417	0.66	2	1.22
1N277	0.41	2	0.82
$\frac{1}{4}$ watt 5% carbon resistor	0.09	8	0.72
$\frac{1}{2}$ watt 5% carbon resistor	0.09	1	0.09
Tantalum capacitor, 10%	1.07	6	6.42
Total			$14.11

B. COST PER CHANNEL, 1,000 OR MORE CHANNELS

Component	Unit Price	Units/ Channel	Subtotal
RCA CA3048	$2.45	$\frac{1}{4}$	$0.61
2N3417	0.30	2	0.60
1N277	0.26	2	0.52
$\frac{1}{4}$ watt 5% carbon resistor	0.06	8	0.48
$\frac{1}{2}$ watt 5% carbon resistor	0.06	1	0.06
Tantalum capacitor 10%	0.41	6	2.46
Total			$4.73

*Three sections not used.

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13. ABSTRACT

A mosaic transducer array at the focal plane of an acoustic lens followed by suitable electronic circuitry can be used to produce an image of an object.

Previous work in developing such a system has resulted in switching and scanning circuits required to use a cathode ray tube display. This report is a study of a design which would use a mosaic of light emitting diodes to produce the image directly without recourse to scanning. A single channel of such a system has been designed which responds to voltage levels at the tranducer of less than ten microvolts at a frequency of 500 KHz. The channel responds to signal levels over a dynamic range of greater than 40 dB and produces light with a dynamic range of 28.9 dB, with 230 to 500 milliwatts power required depending on the input signal level. A discussion of performance, size and cost is included.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Acoustic Imaging						
Ultrasonic						
Ultrasonic Image Converter						
Light Emitting Diode						
Luminescent Diode						
Mosaic Transducer						
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